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Integration of Unified Power Quality Controller with DG

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ABSTRACT

This paper gives an insight into the analytical results of the intergration of Unified power quality controller (conditioner) with distribution generation system. The intergration is achieved by connecting the DClink throught rectifier to the distribution generatoion along with thwe connection of the series and shunt inverter to the same dc link. This type of connection can account for the voltage sag, voltage swell, along with the reduction of harmonics and also compensation of reactive power. The analysis is supported with the simulation which will are discussed in detail in the paper.

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I. INTRODUCTION

Power quality determines the fitness of electric power to consumer devices. Synchronization of the voltage frequency and phase allows electrical systems to function in their intended manner without significant loss of performance or life.

The main reason for the power quality problems to arise is due to circuit breakers trip, equipment failure . UPQC is the device that is used to improve power quality but due to absence of energy storage it cant mitigate voltage interruption

II. BASIC CONFIGURATION OF UPQC

A UPQC is a combination of shunt and series APFs, sharing a common dc link. It is a versatile device that can compensate almost all power quality problems such as voltage harmonics, voltage unbalance, voltage flickers, voltage sags & swells, current harmonics, current unbalance, reactive current, etc. The Unified Power Quality Conditioner (UPQC) has evolved to be one of the most comprehensive custom power solutions for power quality issues relating to non-linear harmonic producing loads and the effect of utility voltage disturbance on sensitive industrial loads.

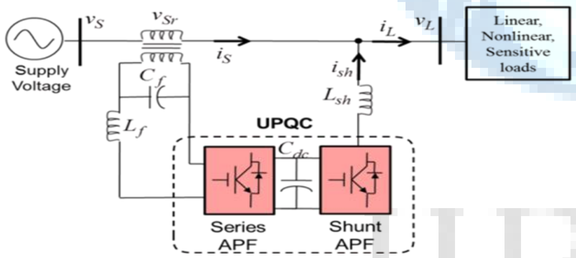


Figure 1 Basic Configuration of UPQC

III. UPQC WITH DG

This paper proposes a new configuration of UPQC that has a DG connected to the dc link through the rectifier as shown in Fig. 1. The UPQC can compensate the voltage interruption in the source, while the DG supplies power to the source and load or the load only. There are two operation modes in the proposed system. One is called the interconnected mode, in which the DG provides power to the source and the load. The other is called the islanding mode, in which the DG provides power to the load only within its power rating.

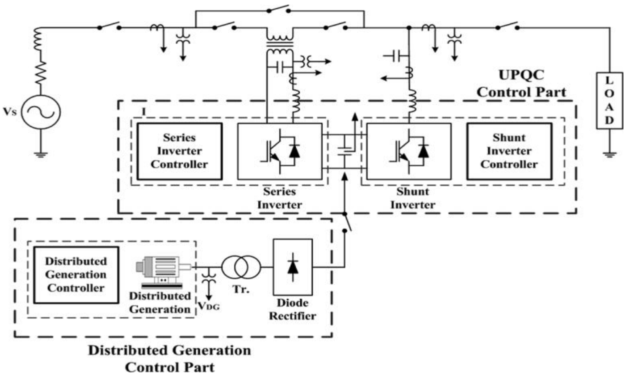


Figure 2: UPQC with DG

UPQC with DG consists of a series inverter , a shunt inverter, and a distributed generator connected in the dc link through rectifier . UPQC can compensate almost existing PQ problems in the transmission and distribution grid Integration of UPQC with DG works in both Interconnected mode and Islanded Mcontrol block diagram of upqc

IV. CONTROL BLOCK DIAGRAM OF UPQC

The control structure of proposed system is shown in Fig. 2. Three major elements are the positive sequence detector, the se-ries inverter control, and the shunt inverter control. The con-trol strategy was designed for implementing the interconnected mode and the islanding mode. The system works in interconnected mode , and also in islanding mode when the voltage interruption occurs. Once the voltage interruption is re-moved, the system operation transfers from the islanding mode to the interconnected mode

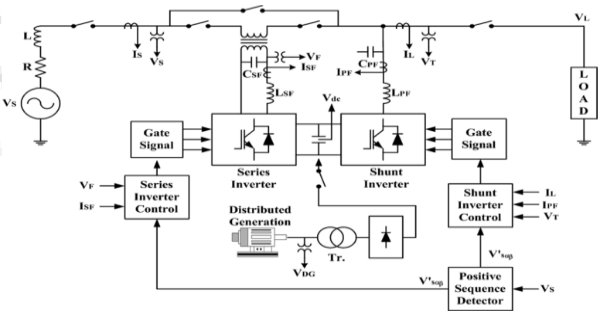


Figure 3: Control block Diagram of UPQC

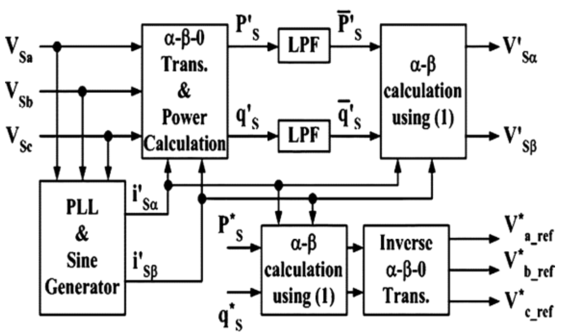
Normally, UPQC has two voltage-source inverters in three-phase four-wire or three-phase three-wire configuration. One inverter called the series inverter is connected through transformers between the source and the common connection point. The other inverter called the shunt inverter is connected in parallel with the common connection point through trans-formers. The series inverter operates as a voltage source, while the shunt inverter operates as a current source.

DG might play an important role in the future power system. DG can solve many typical problems that the conventional ac power system has. For example, an energy security problem occurs in the large-scale power system because a few transmission facilities are responsible for serving electric power to a great number of customers. This security problem caused by some transmission-line trip can be alleviated if a large number of DGs are installed in the power system. Moreover, DG can yield economic benefits, such as reducing the loss of transmission line and the cost of high-voltage equipment. However, a small DG has some significant problems of frequency and voltage variation when it is operated in stand-alone mode. Therefore, a small DG should be interconnected with the power system in order to maintain the frequency and the voltage. Several studies proposed an interconnection system for DG with the power system through the inverter because the inverter gives versatile functions improving the ability of DG.

UPQC has compensation capabilities for the harmonic cur-rent, the reactive power compensation, the voltage disturbances, and the power-flow control. But UPQC has no capability in compensating the voltage interruption because there is no energy storage. The UPQC can compensate the voltage interruption in the source, while the DG supplies power to the source and load or the load only. There are two operation modes in the proposed system. One is called the interconnected mode, in which the DG provides power to the source and the load. The other is called the islanding mode, in which the DG provides power to the load only within its power rating.

V. Positive Sequence Detector and Voltage Reference Generator

The positive sequence detector has a configuration shown in Fig. 3. The source voltage is detected to calculate the fundamental current component i1=sin(wt) and i2=cos(wt) passing through the phase-locked loop (PLL) and the sine-wave generator. The reference voltages are derived from the nominal instantaneous active and reactive power p_* and q_* using particular related equation and inverse α_β_0 transformation.



A. Series Inverter Control

The function of series inverter is to compensate the voltage disturbance in the source side, which is due to the fault in the distribution line. The series inverter control calculates the reference value to be injected by the series inverter, comparing the positive-sequence component with the disturbed source voltage. Equation (2) shows the state equation of the Series inverter

Vc*= [Kpi{ (Vref* -Vs) –Vf }-Isf] * K +Vf*

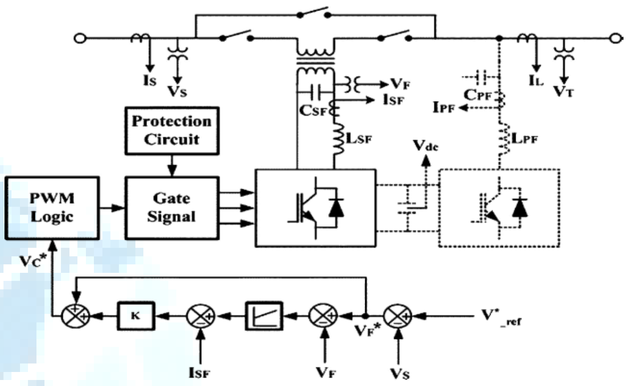


Figure 4: Series Inverter Control

B. Shunt Inverter Control

It compensates the current harmonics generated in non linear load and reactive power.It supply power to load when voltage interruption occurs in the source side then the DG provides the active power to maintain load voltage. In case of voltage interruption in the source side , the shunt inverter control changes from the operation of active power filter to that of uninterruptable power supply

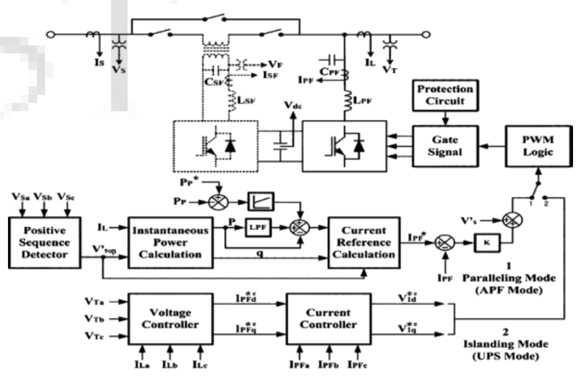


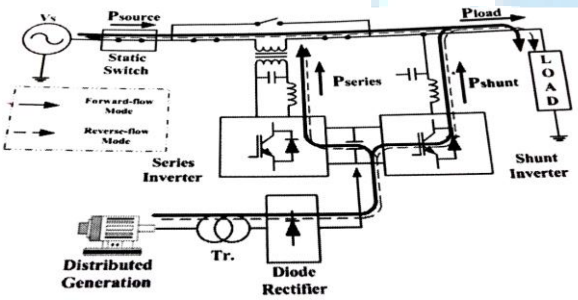
Figure 5: Shunt Inverter Control

When the voltage interruption occurs in the source side, the shunt inverter control changes from the operation mode of active power filter to that of the uninterruptible power supply. Fig. 6 shows the configuration of whole system control, which includes three sub control elements, such as

the current control for harmonic compensation, and the output voltage control in voltage interruption

C. Interconnected Mode

In the interconnected mode, the operation is divided into two sub modes according to the direction of power flow. One is called the forward-flow mode, in which the shunt inverter with the DG supplies power to the load in parallel with the main source. The other, called the reverse-flow mode, is when the shunt inverter with DG supplies power to the load and the main source. It is assumed that the shunt inverter and the main source provide 20-kW power to the load in the forward-flow mode, and the shunt inverter provide 10-kW power to the main source and 10-kW power to the load in the reverse-flow mode. When the voltage interruption occurs, the proposed UPQC changes from the interconnected mode to the islanding mode, and the shunt inverter provides 10-kW power to the load.



(a)

DG source will deliver only the fundamental active power to the grid,storage and load.Voltage sag , swell , interruption can be compensated by the active power from the grid. It has forward flow mode,reverse flow mode . Forward mode --- when available power is less than the required load demand. Reverse mode ---when available power is higher than the required load demand.

D. Reactive Power

Reactive power is the power that supplies the stored energy in reactive elements. Power, as we know, consists of two components, active and reactive power. The total sum of active and reactive power is called as apparent power. In AC circuits, energy is stored temporarily in inductive and capacitive elements, which results in the periodic reversal of the direction of flow of energy between the source and the load. The average power after the completion of one whole cycle of the AC waveform is the real power, and this is the usable energy of the system and is used to do work, whereas the portion of power flow which is temporarily stored in the form of magnetic or electric fields and flows back and forth in the transmission line due to inductive and capacitive network elements is known as reactive power.

This is the unused power which the system has to incur in order to transmit power. Inductors (reactors) are said to store or absorb reactive power, because they store energy in the form of a magnetic field. This in turn causes the current to lag the voltage in phase.12 Capacitors are said to generate reactive power, because they store energy in the form of an electric field. Therefore when current passes through the capacitor, a charge is built up to produce the full voltage difference over a certain period of time. Since, the capacitor tends to oppose this change , it causes the voltage to lag behind current in phase.

In an inductive circuit, we know the instantaneous power to be :

$$p = V_{max} I_{max} \cos \omega t \cos(\omega t - \theta)$$

$$p = \frac{VmaxImax}{2} \cos\theta \,(1 + \cos 2\omega t) + \frac{VmaxImax}{2} \sin\theta \sin 2\omega t$$

Where:
p = instantaneous power
Vmax = Peak value of the voltage waveform
Imax = Peak value of the current waveform
ω = Angular frequency = 2πf where f is the frequency of the waveform.
t = Time period
θ = Angle by which the current lags the voltage in phase
From here, we can conclude that the instantaneous reactive power pulsates at twice the system frequency and its average value is zero and the maximum instantaneous reactive power is given by:

$Q = |V|\,|I| \sin\theta$

The zero average does not necessarily mean that no energy is flowing, but the actual amount that is flowing for half a cycle in one direction, is coming back in the next half cycle.

VI. SIMULATION MODEL

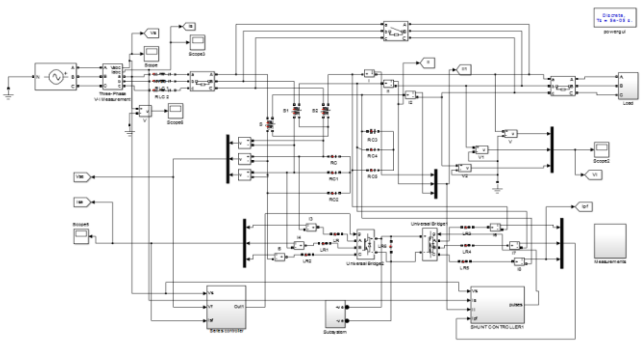


Figure 7: Simulink Model for Voltage Sag

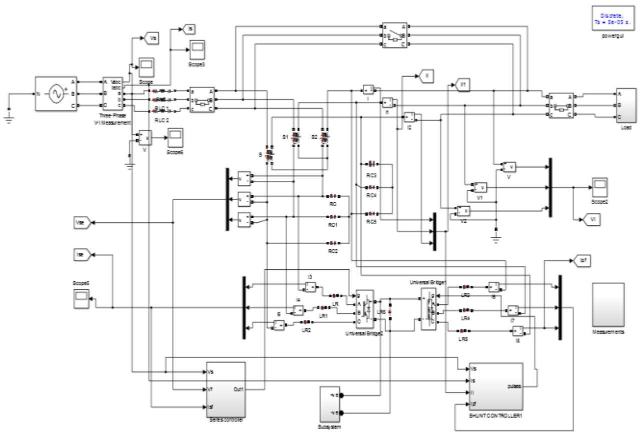


Figure 8: Simulink Model for Voltage Swell

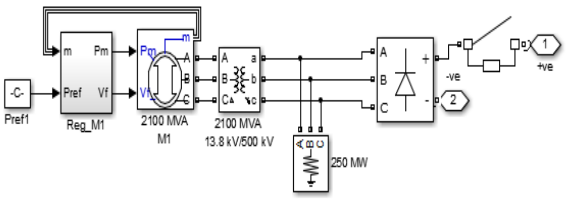


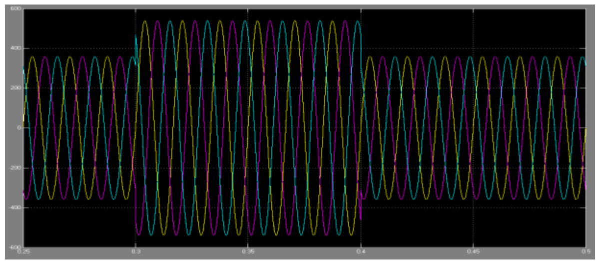
Figure 9: Subsystem for distributed generation

The performance of the proposed concept of voltage sag & swell compensation is evaluated based on the simulation.. DG can be used to solve many problems as faced by the present ac system. This paper describes analysis results of integration of the unified power quality conditioner with the distributed generation. UPQC has two voltage-source inverters in three-phase four-wire or three-phase three-wire configuration. One inverter called the series inverter is connected through transformers between the source and the common connection point. The other inverter called the shunt inverter is connected in parallel with the common connection point through trans-formers. The series inverter operates as a voltage source, while the shunt inverter operates as a current source UPQC has compensation capabilities for the harmonic cur-rent, the reactive power compensation, the voltage disturbances, and the power-flow control. But UPQC has no capability in compensating the voltage interruption because there is no energy storage.

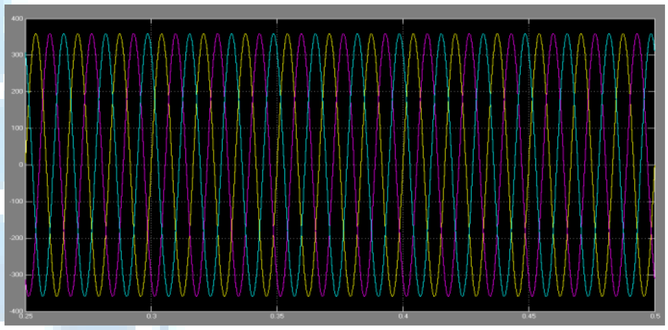
The proposed system consists of a series inverter, a shunt inverter, and a distributed generator connected in the dc link through rectifier. The proposed system can compensate voltage sag and swell, voltage interruption, harmonics, and reactive power in both interconnected mode and islanding mode. The performance of proposed system was analyzed using simulations with power system computer aided design/electromagnetic transients dc analysis program.

VII. Simulation Results

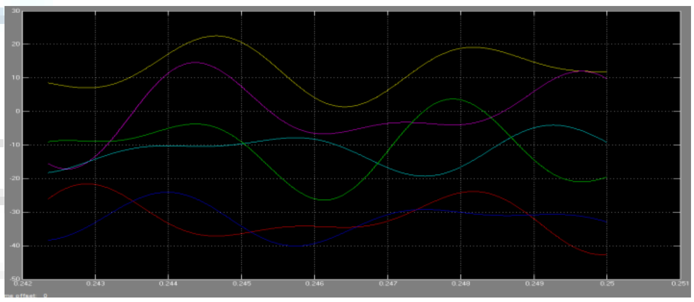
A. Results for the voltage swell compensation under reverse mode:



X: time in sec
Y: source voltage v
FIG 10.1 SOURCE VOLTAGE

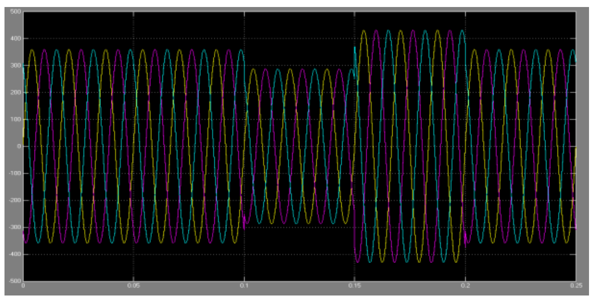


X: Time in sec
Y: load voltage V
FIG 10.2 LOAD VOLTAGE



X: Time(sec)
Y:Active power(kw)
FIG 10.3 ACTIVE POWER VARIATION

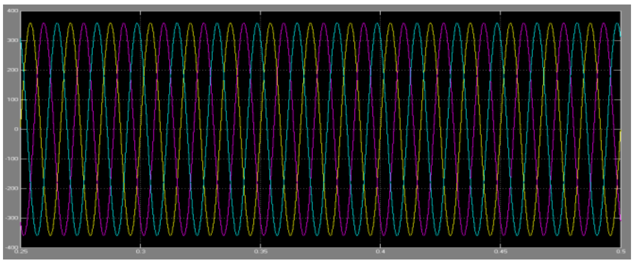
B. Results for voltage sag compensation under forward mode:



X: Time(sec)

Y: Source Voltage

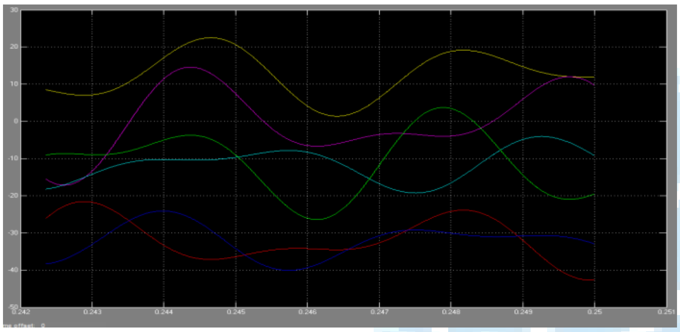
FIG 10.4 SOURCE VOLTAGE



X: Time(sec)

Y:Load Voltage

FIG 10.5 LOAD VOLTAGE

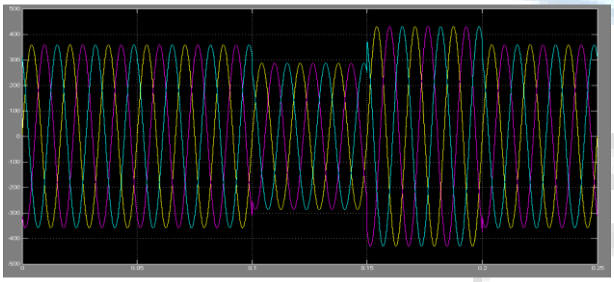


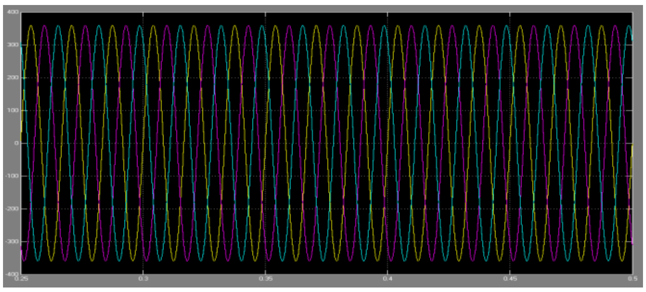
X: Time(sec)

Y:Active power(kw)

FIG 10.6 ACTIVE POWER VARIATION

Results For Voltage Sag Compensation Under Reverse Mode

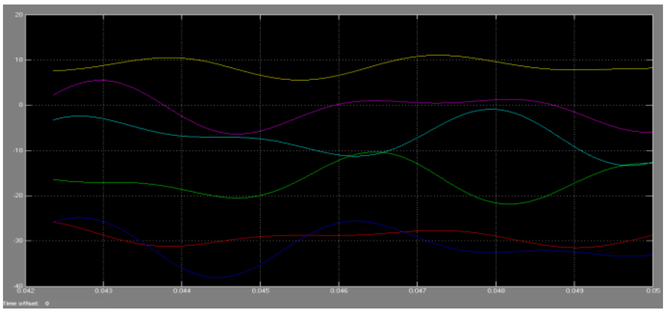




X: Time(sec)

Y:Load Voltage

FIG 10.8 LOAD VOLTAGE



X: Time(sec)

Y:Active power(kw)

FIG 10.9 ACTIVE POWER VARIATION

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